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TETRAETHYL DITHIOPYROPHOSPHATE IN AEROSOLS FOR THE CONTROL OF GREENHOUSE INSECTS

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Tetraethyl dithiopyrophosphate in aerosols is highly toxic to spider mites, aphids, whiteflies, and mealybugs and relatively low in phytotoxicity, according to experiments conducted at Beltsville, Md., and in commercial greenhouses during the last 2 years. These aerosols were compared with aerosols containing hexaethyl tetraphosphate (containing 12 to 15 percent of tetraethyl pyrophosphate) and tetraethyl pyrophosphate (35 to 40 percent). The three materials were found to be toxic to the same species of mites and insects, but tetraethyl dithiopyrophosphate was the most effective against the resistant two-spotted spider mite (*Tetranychus bimaculatus* Harvey) on roses, mealybugs on various crops, and whiteflies on vegetables (Smith *et al.* 3). It has also proved non-injurious to a large number of greenhouse crops, including chrysanthemums and seedling tomatoes of the varieties most susceptible to injury by aerosols containing tetraethyl pyrophosphate.

Experiments on the control of spider mites and other greenhouse pests, on the speed of killing action and persistence of toxicity, and on host-plant tolerance to this insecticide are reported herein. This information will give manufacturers and florists a basis for preparing aerosols containing tetraethyl dithiopyrophosphate, and for applying them on greenhouse crops.

An aerosol containing 5 percent of technical tetraethyl dithiopyrophosphate in methyl chloride was used (Formula A-178). An equal quantity of acetone was added to reduce the precipitate that formed in the aerosol prepared from the original lot of tetraethyl dithiopyrophosphate. Later samples were apparently more highly refined and the acetone was not required.

Tests Against Spider Mites

Because of the interest in finding an effective aerosol for the resistant spider mite, tests were made to compare the effectiveness of tetraethyl dithiopyrophosphate, parathion, hexaethyl tetraphosphate, and tetraethyl

pyrophosphate on similar populations of mites in active stages (table 1). Although all four materials in aerosol form were effective against active stages of the nonresistant strain of spider mite, tetraethyl dithiopyrophosphate consistently destroyed more larvae and more adults of the resistant strain than did the other materials. No increase in kill of resistant mites was obtained by doubling the rates of application of any of these materials. Exposures for 4 hours to parathion and for 2 hours to the other materials were equal in effectiveness to overnight exposures with the same dosage of each material.

Table 1.--Effectiveness of tetraethyl dithiopyrophosphate and other organic phosphates in aerosols against two strains of spider mites

Insecticide	Formula	Dosage of phosphate per 1000 cu. ft.	Mortality			
			Nonresistant mites		Resistant mites	
			Adults	Larvae	Adults	Larvae
		Grams	Percent	Percent	Percent	Percent
Tetraethyl dithiopyrophosphate 5%	A-178	0.5	100	100	68	97
Parathion 10%	A-151	1.	99	100	3	0
Hexaethyl tetraphosphate 5%	A-107	.5	100	100	30	61
Tetraethyl pyrophosphate 5%	A-153	.25	100	100	4	46

Five applications of tetraethyl dithiopyrophosphate aerosol in commercial greenhouses at 3-day intervals, with exposures for 2 hours or overnight and temperatures near 80° F. at the time of release, reduced heavy infestations of resistant mites to a few scattered individuals. Weekly applications did not prevent a slow increase in population and occasionally in commercial greenhouses it has been necessary to repeat this series of five applications.

Tests Against Other Greenhouse Pests

In tests with other pests, aphids of seven species were readily killed where not concealed between leaves or flower parts (table 2). Although green peach aphids exposed between the outer leaves of nearly grown lettuce were killed, protected individuals among the inner leaves gradually increased in numbers, even though weekly applications of aerosols were being made.

In comparative tests in which weekly applications were made, better control of whiteflies on tomatoes and cucumbers was obtained with tetraethyl dithiopyrophosphate than with hexaethyl tetraphosphate.

Tetraethyl dithiopyrophosphate proved more effective than parathion against grape mealybugs on carnation and gerbera, Mexican mealybugs on chrysanthemum, and citrus mealybugs on gardenia. The eggs were not killed, and four weekly applications appeared to be necessary for reduction of established infestations.

Exposed adults and larvae of the chrysanthemum thrips and of the banded greenhouse thrips were killed by tetraethyl dithiopyrophosphate, but concealed individuals escaped, and because of lack of residue less effective results were obtained than with DDT aerosols.

Only exposed Pharaoh ants were killed, and there was no kill of cyclamen mites and broad mites.

Table 2.--Effect of tetraethyl dithiopyrophosphate aerosols on greenhouse pests other than the two-spotted spider mite.

Pests	Pests examined	Pests killed
	Number	Percent
Aphids:		
Leaf curling plum (*Anuraphis helichrysi* (Kltb.))	256	100
Foxglove (*Myzus convolvuli* (Kltb.))	181	100
Melon (*Aphis gossypii* Glov.)	205	100
Green chrysanthemum (*Rhopalosiphum rufomaculatum* (Wilson))	209	100
Black chrysanthemum (*Macrosiphoniella sanborni* (Gill.))	166	100
Potato (*Macrosiphum solanifolii* (Ashm.))	224	100
Green peach (*Myzus persicae* (Sulz.))	387	100
Thrips:		
Banded greenhouse (*Hercinothrips femoralis* (Reut.))	84	100
Chrysanthemum (*Thrips nigropilosus* Uzel)	172	98
Mealybugs:		
Mexican (*Phenacoccus gossypii* T. and C.)	724	100
Grape (*Pseudococcus maritimus* (Ehrh.))	320	100
Citrus (*P. citri* (Risso))	360	100
Greenhouse whitefly (*Trialeurodes vaporariorum* (Westw.))	1240	99
Broad mite (*Hemitarsonemus latus* (Banks))	210	0
Cyclamen mite (*Tarsonemus pallidus* Banks)	520	0
Pharaoh ant (*Monomorium pharaonis* (L.))	45	100

Speed of Killing Action and Persistence of Toxicity

The florist applying tetraethyl dithiopyrophosphate aerosols in his greenhouse has need for information on the length of time the ventilators should be kept closed in order to effect control, and also on the persistency of toxic residues that would affect workers in the greenhouse after the fumigation. Experiments were therefore conducted with mites and aphids to determine the speed of killing action and the duration of toxicity of tetraethyl dithiopyrophosphate.

Fulton et al. (2) had shown that 77 to 96 percent of the two-spotted spider mites (nonresistant strain) were killed after only 2 minutes' exposure to a 10-percent hexaethyl tetraphosphate aerosol released in a greenhouse, that maximum kills were obtained after 10 minutes' exposure; and that the toxicity declined after the second hour. In a similar experiment tetraethyl dithiopyrophosphate aerosol also showed rapid killing action against mites of the same strain (table 3). In this experiment 70 grams of an aerosol containing 5 percent of tetraethyl dithiopyrophosphate in methyl chloride was released in two adjacent sections of a greenhouse, each containing 7000 cubic feet. One section served as an entrance chamber to prevent loss of aerosol in the other section. The temperature ranged from 71° to 81° F. and the relative humidity was 60 percent at the beginning of the experiment. The potency of the aerosol did not begin to decline until after the third hour, and 70 percent mortality was obtained of mites brought into the house 6 hours after release of the aerosol.

Table 3. --Effect of time and duration of exposure on the mortality of nonresistant spider mites after release of 5-percent tetraethyl dithiopyrophosphate aerosol

Aerosol treatment		Mites examined	Mites killed
Time between release and beginning of exposure	Duration of exposure		
Minutes	Minutes	Number	Percent
None	2	130	88
	5	162	99
	10	106	98
	15	229	100
	30	215	100
	60	239	100
30	30	202	100
60	60	177	100
120	60	336	100
180	60	288	89
240	120	187	90
360	120	240	70

In other experiments with overnight exposures (16 hours) no kills were obtained of two-spotted spider mites or foxglove aphids on plants placed in the house for 4 hours the next morning, with the ventilators kept closed.

In short-exposure experiments on residual toxicity of tetraethyl dithiopyrophosphate, the greenhouses were ventilated for 30 minutes after a 2-hour exposure period and then closed for 4 hours. During this post-ventilation period, plants bearing mites and aphids were held in the house but no kill was obtained.

Colonies of nonresistant two-spotted spider mites were established on rose and bean, and colonies of foxglove aphids on potato, within 24 hours after the plants had been exposed to tetraethyl dithiopyrophosphate aerosol.

These experiments indicate that tetraethyl dithiopyrophosphate retains its residual toxicity slightly longer than hexaethyl tetraphosphate, but only for a few hours after its release as an aerosol.

Tolerance of Plants to Tetraethyl Dithiopyrophosphate

A large number of plants in experimental and commercial greenhouses have been treated from one to eight times with tetraethyl dithiopyrophosphate in 5-percent aerosols applied at the rate of 1 pound of aerosol per 50,000 cubic feet. No injury has been observed on these plants except that an occasional tip of a tender unfolding leaflet of greenhouse roses failed to expand normally, so that the full-grown leaf was slightly cupped and the tip was puckered. This abnormality has been observed on roses in adjacent houses treated at the same time with tetraethyl pyrophosphate aerosol. This injury appears to be correlated with temperatures of 90° F. or higher and is not specific for tetraethyl dithiopyrophosphate.

The following plants were included in these tests (those marked by asterisk (*) were in flower:

African violet, *Saintpaulia ionantha**, 10 varieties
Alfalfa, *Medicago sativa*, var. Common Kansas
Amaranthus, horticultural varieties
Amaryllis, *Amaryllis belladonna**
Asparagus, *Asparagus plumosus* and *A. sprengeri*
Aucuba, *Aucuba japonica variegata*
Azalea, *Azalea kinsiana* kurume varieties*
Banana, *Musa paradisiaca sapientum*
Bean, *Phaseolus vulgaris*, var. Stringless Greenpod
Begonia, *Begonia lucerna**, *B. rex* var., *B. semperflorens**
Boxwood, *Buxus sempervirens* and vars. *suffruticosa* and *arborescens*
Bryophyllum, *Bryophyllum pinnatum*
Cabbage, *Brassica oleracea capitata* var. Wakefield
Caladium, *Caladium bicolor*, vars.
Carnation, *Dianthus caryophyllus*, most commercial varieties*, large collection of seedlings*

Chinese evergreen, Aglaonema simplex
Christmas cactus, Zygocactus truncatus*
Chrysanthemum, Chrysanthemum morifolium, 120 varieties*
Coleus, Coleus blumei, 5 varieties
Common yam, Dioscorea sativa
Cotton, Gossypium hirsutum
Crassula, Crassula arborescens, C. multicava (C. quadrifida)
Croton, Codiaeum variegatum, var.
Cucumber, Cucumis sativus var. White Spine*
Datura, Datura meteloides, D. stramonium
Dusty-miller, Centaurea cineraria
Endive, Cichorium endivia
English ivy, Hedera helix, several varieties
Ferns:
Maidenhair, Adiantum pedatum
Cibotium, Cibotium regale
Boston, Nephrolepis exaltata bostoniensis
Fig, Ficus carica
Fuchsia, Fuchsia hybrida*
Funkia, Hosta caerulea
Gardenia, Gardenia veitchi*, and horticultural varieties
Geranium, Pelargonium domesticum*, P. hortorum*
Gerbera, Gerbera jamesoni*
Gingerlily, Hedychium coronarium
Gladiolus, vars. Picardy and La Paloma
Grapefruit, Citrus paradisi
Groundcherry, Physalis angulata
Husk tomato, Physalis edulis
Jerusalem cherry, Solanum pseudocapsicum
Lantana, Lantana camara
Lettuce, Lactuca sativa
Lily, Lilium longiflorum
Lima bean, Phaseolus lunatus macrocarpus, var. Henderson bush
Maranta, Maranta goveniana
Marigold, Tagetes erecta, T. patula
Okra, Hibiscus esculentus
Oleander, Nerium oleander*
Orange, Citrus sinensis var.
Oxalis, Oxalis enneaphylla rosea
Papaya, Carica papaya
Parsley, Petroselinum crispum
Peach, Amygdalus persica, seedlings
Peanut, Arachis hypogaea
Pepper, Capsicum frutescens
Periwinkle, Vinca minor, V. rosea*
Philodendron, Philodendron giganteum
Phlox, Phlox decussata, perennial varieties
Pineapple, Ananas comosus
Poinsettia, Euphorbia pulcherrima*
Potato, Solanum tuberosum
Rhoeo, Rhoeo discolor
Rose, Rosa spp. var. --
Better Times*
Starlight*
Golden Rapture*
Brandywine*
Yellow Gloria*
Rose geranium, Pelargonium graveolens
Rose of Sharon, Hibiscus rosa sinensis
Sansevieria, Sansevieria zeylanica
Shrimp plant, Beloperone guttata
Snapdragon, Antirrhinum majus, many varieties and seedlings*
Stephanotus, Stephanotis floribunda*
Stonecrop, Sedum spp.
Sultan snapweed, Impatiens sultani

Sweet marjoram, Origanum majorana
Tobacco, Nicotiana tabacum, var. Gold Dollar
Tomato, Lycopersicon esculentum var. --
Bay State
Globe, strains A and wilt-resistant strains 2, 3, and 5
Italian Salad
Marglobe
Marhio
Michigan State
Pan American
Ponderosa
Rutgers
Sunrise
Waltham Forcing
Top primrose, Primula obconica*
Wandering jew, Tradescantia fluminensis
Yew, Taxus cuspidata

In two experiments on October 29, 1948, with tetraethyl dithiopyrophosphate at 4 and 8 pounds of 5-percent aerosol per 50,000 cubic feet, (4 and 8 times the normal dosage) at 82° F. and 58 percent relative humidity, the following plants were treated without injury:

African-violet*
Bean, Stringless Greenpod
Begonia semperflorens*
Cabbage
Carnation, var. Arundel*
China aster*
Chrysanthemum, vars. Arcadia and Mary McArthur
Coleus, 5 varieties
Fuchsia*
Geranium, 5 varieties*
Kalanchoe globulifera

In a test on March 4, 1949, the 4-pound dosage caused no injury on tender growth of Datura, groundcherry, husk tomato, and pepper, but caused small necrotic spots on potato foliage and on flowers only of Vinca rosea.

Ten varieties of tomatoes growing in 3-inch pots, and having two to three true leaves in succulent growth, showed the following degrees of leaf burning from dosages of 4 and 8 pounds of this aerosol per 50,000 cubic feet:

Tomato variety	4 pounds	8 pounds
Globe, strain A	Slight	Severe
Globe, wilt-resistant strains 3 and 5	Slight	Moderate
Italian Salad	Moderate	Severe
Marglobe	Slight	Moderate
Marhio	Slight	Moderate
Michigan State	None	None
Pan American	Slight	Moderate
Rutgers	Moderate	Severe
Sunrise	Slight	Severe
Waltham	Slight	Moderate

Italian Salad appeared to be the tomato variety most susceptible to excessive dosages of tetraethyl dithiopyrophosphate, and it was also the most susceptible of the more than 80 varieties tested with hexaethyl tetraphosphate and tetraethyl pyrophosphate.

These experiments indicate that tetraethyl dithiopyrophosphate has a much wider margin of safety on even the most tender plants than has hexaethyl tetraphosphate or tetraethyl pyrophosphate.

Preparation and Use

Tetraethyl dithiopyrophosphate aerosol is similar to a hexaethyl tetraphosphate aerosol in preparation and application in the greenhouse (Smith et al. 4). Both are effective against the two-spotted spider mite, aphids, whiteflies, and mealybugs, but tetraethyl dithiopyrophosphate has shown the greater toxicity against these pests and also against the parathion-resistant strain of spider mites.

When properly applied, tetraethyl dithiopyrophosphate is also safe to use on many greenhouse crops, including seedling tomatoes and tender chrysanthemums. It has shown no tendency to cause plant injury in the presence of other insecticides or fungicides. The aerosol should contain 5 percent of tetraethyl dithiopyrophosphate in methylene chloride. Four pounds of this aerosol (known as formula A-178) will contain 3.2 ounces (91 grams) of the toxicant.

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Application.--Tetraethyl dithiopyrophosphate aerosol may be applied during the day at a temperature near 80° F. if the ventilators can be kept closed for 1 or 2 hours. It may also be applied in late afternoon or evening and left overnight. Although toxic to susceptible pests, including the usual strain of spider mite, at 70°, against the resistant kinds it appears to be more effective at 80°. However, the temperature should not rise above 90° during the exposure period. If it does, the ventilators should be opened.

Hold the aerosol container with the valve down and open the valve one full turn. Walk slowly down the aisle and move the applicator from side to side, so that the aerosol will discharge into the air above the plants. Two to four benches can be treated from one path.

Apply the tetraethyl dithiopyrophosphate aerosol at the rate of 1 pound per 50,000 cubic feet of space, or a discharge rate of approximately 4 seconds per 1000 cubic feet by means of an applicator with a No. 5 tip. The temperature of the aerosol solution should be about 80° F. Weigh the cylinder frequently and adjust the treating time accordingly to obtain the desired application rate.

The frequency of application found most effective against various pests is given below:

Two applications against the two-spotted spider mite, aphids, and the susceptible strain or five applications against resistant mites, all at 3-day intervals.

http://archive.org/details/tetraethio00unit

Greenhouse whitefly: Four applications at weekly intervals.

Mealybug: Four applications at weekly intervals or three applications at 10-day intervals.

Aphids: One or more applications as needed.

Thrips: Three or more applications at weekly intervals (effective only against exposed thrips).

Residue Hazard. --Tetraethyl dithiopyrophosphate, like other phosphate insecticides, is highly poisonous. Although under the conditions of these experiments this material dissipated rapidly, as indicated by chemical analysis and the mortality of mites, data on cumulative residues are incomplete. Therefore, it is advisable not to use it on greenhouse tomatoes or cucumbers when in bearing or on leafy vegetables at any time.

Ventilation. --At the end of the 2-hour exposure period open the house and ventilate thoroughly before permitting work to be done there. No special ventilation seems necessary at the end of an overnight fumigation, because the aerosol is active for only about 8 hours.

Care of Equipment. --After the application thoroughly clean the nozzle tip and screen with soap and hot water, and dry before reassembling the nozzle.

After continuous use with tetraethyl dithiopyrophosphate it will be necessary to clean the cylinders. A satisfactory method was recently described by Fulton (1).

Personal Protection. --When applying aerosols, avoid skin exposure by wearing gloves, a special coverall or smock with the collar turned up, and a cap with the visor turned back. Avoid inhaling fumes by wearing a full-face gas mask of the type approved by the U.S. Department of Agriculture for toxic dusts and gases.

Immediately after application remove the outer clothing and wash any exposed or wetted skin surface with soap and water.

If through accident during application the skin is wetted with aerosol solution, remove the clothing promptly and wash the area thoroughly.

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